YELLOWSTONE LAKE TROUT CREEL CENSUSES, 1950 - 51

SPECIAL SCIENTIFIC REPORT: FISHERIES No. 81

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

YELLOWSTONE LAKE TROUT CREEL CENSUSES, 1950 - 51

SPECIAL SCIENTIFIC REPORT: FISHERIES No. 81

UNITED STATES DEPARTMENT OF THE INTERIOR

FISH AND WILDLIFE SERVICE

Explanatory Note

The series embodies results of investigations, usually of restricted scope, intended to aid or direct managment or utilization practices and as guides for administrative or legislative action. It is issued in limited quantities for the official use of Federal, State or cooperating agencies and in processed for economy and to avoid delay in publication.

Washington, D. C.
September 1952

United States Department of the Interior, Oscar L. Chapman, Secretary
Fish and Wildlife Service, Albert M. Day, Director

YELLOWSTONE LAKE TROUT CREEL CENSUSES, 1950-51

by

Harvey L. Moore and Oliver B. Cope
Fishery Research Biologists
and
Richard E. Beckwith
Analytical Statistician
U. S. Fish and Wildlife Service

Special Scientific Report: Fisheries No. 81

CONTENTS

Page

Fishing pattern 2

Census method 4

Fishing Bridge Dock 5

West Thumb Dock 14

Fishing Bridge 18

Lake shore census 19

Private boat fishery 23

Yellowstone River 27

Conclusion 29

Mathematical derivation of creel census estimates 32

FIGURES

No.		Page
1	Map of Yellowstone Lake showing boat docks and prominent fishing areas	3
2	Biweekly means of effort and catch-per-unit-effort plotted against the mid-point of each period; rowboat fishery, Fishing Bridge dock, 1950 and 1951	8
3	Total hours of fishing effort of biweekly periods plotted against the mid-point of each period; rowboat fishery, Fishing Bridge dock, 1950 and 1951	8
4	Total catch of biweekly periods plotted against the mid-point of each period; rowboat fishery, Fishing Bridge dock, 1950 and 1951	10
5	Total catch of guideboats, Fishing Bridge dock, 1950 and 1951. Catch of biweekly periods plotted against the mid-point of each period	10
6	Biweekly means of effort and catch-per-unit-effort plotted against the mid-point of each period; rowboat fishery, West Thumb dock, 1950 and 1951	15
7	Total hours of fishing effort of biweekly periods plotted against the mid-point of each period, rowboat fishery, West Thumb dock, 1950 and 1951	15
8	Total catch of biweekly periods plotted against the mid-point of each period, rowboat fishery, West Thumb dock, 1950 and 1951	15
9	Rate of catch-per-unit-effort at Fishing Bridge plotted against time periods, 1951	20
10	Rate of catch-per-unit-effort and total catch by two-week periods for Yellowstone Lake shoreline fishery, 1950 and 1951	20
11.	Complete census worksheet with marginal summaries	36
12	Fishing situation in L_i during the census hour	39
13	Fishing situation in which each fisherman fishes the same expected time	40
14	Modification of Figure 13, with lines replaced by dots and the driving path replaced by a strip	40

TABLES

No.		Page
1	Creel census schedule used during 1951 season	4
2	Chi-square test of 1950 data from Fishing Bridge dock	6
3	Creel census results, Fishing Bridge dock, rowboats, 1950 and 1951	7
4	"t" test of catch-per-unit-effort and effort, rowboat fishery, Fishing Bridge dock, 1950 and 1951	9
5	Creel census results, Fishing Bridge dock, guideboats, 1950 and 1951	11
6	"t" test of catch-per-unit-effort and effort, guideboat fishery, Fishing Bridge dock, 1950 and 1951	12
7	Creel census results, West Thumb dock, rowboats, 1950 and 1951	13
8	"t" test of catch-per-unit-effort and effort, rowboat fishery, West Thumb dock, 1950 and 1951	14
9	Creel census results, West Thumb dock, guideboats, 1950 and 1951	16
10	"t" test of catch-per-unit-effort and effort, West Thumb dock, guideboats, 1950 and 1951	17
11	Creel census results, Fishing Bridge, 1950 and 1951	18
12	Results of shoreline census, 1950 and 1951	22
13	Estimates of total hours and total catch, with variances and standard deviations for each two-week period, 1951	23
14	Mean number of days fishing on the lake, number of anglers in boat, hours, of fishing per boat day, and catch per fisherman hour; road block survey and volunteer census cards, private trailer boats, 1951	25
15	Mean values derived from volunteer creel census cards turned in by trailer-boat fishermen, 1951	25
16	Estimates of total catch by private trailer-type boats for 1950 and 1951	26
17	Results of Yellowstone River census, 1951	28
18	Estimates of total hours and total catch, with variances and standard deviations for each two-week period	28
19	Summary of catch estimates of all units of Yellowstone Lake fishery, 1950 and 1951	31

Yellowstone Lake in Yellowstone National Park, Wyo., has for many years been known for its production of black-spotted or cutthroat trout (Salmo clarkii lewisi), the only species of game fish present. Few lakes in the United States offer recreational fishing equal to that of Yellowstone Lake. With over 100 miles of shoreline and 135 square miles of surface, the lake affords good fly and bait fishing and trolling from private and rented boats. The success of anglers fishing Yellowstone Lake in past years has caused an ever-increasing number to visit its waters. Concurrent with the normal increase attributed to successful fishing, there has been since World War II a Nation-wide increase in travel. During each of the summer seasons of 1940 and 1941, approximately 500,000 persons visited Yellowstone Park. In the war years from 1942 to 1945, there was an expected decrease in visitors which reached a low 100,000 in 1943 and 1944. Since the end of the war there has been an ever-increasing number of visitors; since 1948, the annual number has never been less than a million.

In conjunction with the increase in total visitors, there has been a noticeable increase in the number of anglers. The effects on the Yellowstone Lake fish population of this increased fishing effort has become a problem of utmost concern.

Because of the problem of increased fishing pressure on Yellowstone Lake, the Fish and Wildlife Service, at the request of the National Park Service, initiated an extensive study to learn the effects of the increase, and to make recommendations, based on their findings, for a plan for a sustained yield fishery. This report is concerned with the results of the first two years of creel census studies. The study was initiated in 1950 and expanded in 1951 for collecting data for the determination of total annual fishing mortality. Data were collected in such a manner that fishing effort and success could be analysed for relative annual and intro-seasonal changes, and for differences between major fishing areas of the lake.

The expansion of the 1951 program entailed the development of a practical method of censusing the Yellowstone Lake shoreline and the Yellowstone River. This problem was solved by the mathematical derivation of a census method included in this report as an appendix.

We are grateful to the National Park Service and the Yellowstone Park Company officials and employees, for their enthusiastic cooperation and interest in this study. To W. A. Dunn, Superintendent, U. S. Fisheries Station, Yellowstone Park, we are deeply indebted for his cooperation in furnishing quarters and facilities for this project. Professor A. H. Bowker of the Statistics Department, Stanford University, made suggestions for the development of several features of the statistical presentation.

FISHING PATTERN

Yellowstone Lake presents a varied pattern of fishing activities although most of the angling is done from boats. Two large boat liveries, located at Fishing Bridge and West Thumb, have rental boats for anglers. Eight party-boats with guides are available for fishing the deeper waters of the lake, and approximately 130 rowboats for use with outboard motors or oars can be rented for angling closer to shore. During the 1951 season, party-boats with guides were also available at Lake Dock immediately in front of Lake Hotel.

Two other groups of boats are used for trout fishing on Yellowstone Lake. One of these consists of private boats, some as long as 30 feet, the maximum length permitted on the lake, that are berthed for the season at Fishing Bridge, West Thumb, and Lake docks. The other category of private boats includes the smaller craft brought into the Park on trailers. These boats may be launched at any number of locations along the thirty miles of lake shore accessible from the highway. Most of these boats are kept on the lake for only a few days at a time, but many are brought into the Park from nearby communities several to many times during the season. Also considered in this category are rubber boats which are present in considerable numbers.

Although Yellowstone Lake has over 100 miles of shoreline, only a 30-mile section from West Thumb to the northeastern part of the lake is readily accessible from the highway (fig. 1). Most of this section of shoreline is fished to some extent throughout the season; however, some areas are consistently more popular than others. Within this 30 miles of shoreline is the outlet of Yellowstone Lake into the Yellowstone River. Crossing this outlet is the famous Fishing Bridge on which anglers numbering up to a hundred can be seen at most any time during the season. Because of this continuous concentration of anglers on the bridge, it has been treated as a unit separate from the shoreline in this study. As tagging studies have indicated that the fish in the Yellowstone River above the Yellowstone Falls are of the same population as those in Yellowstone Lake, the river fishery has been included as another unit in the creel census program.

In order to efficiently sample the fishing activities, the different aspects of the fishery were set up as individual units in accordance with the fishing pattern.

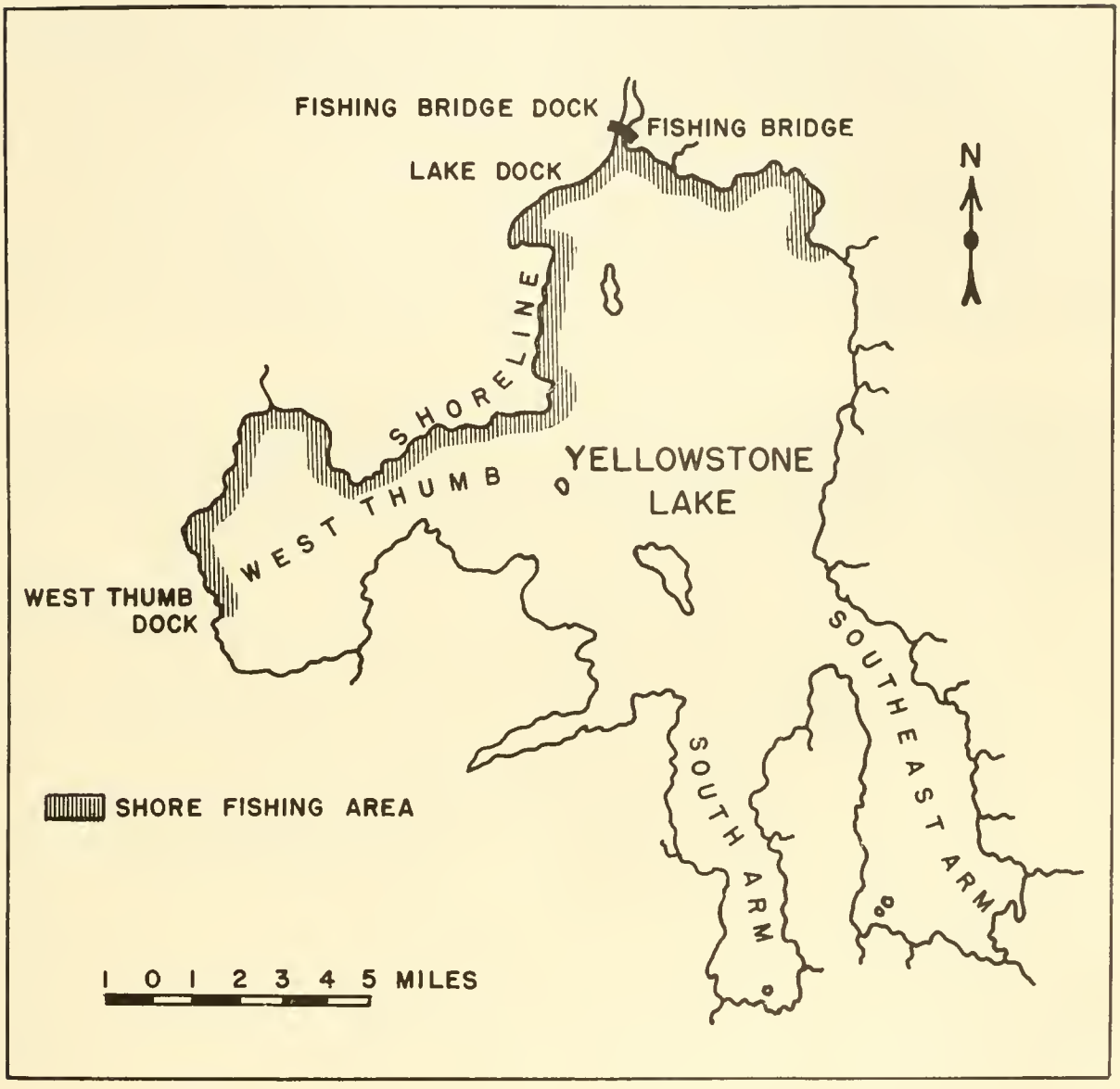

Figure 1. Map of Yellowstone Lake showing boat docks and prominent fishing areas.

CENSUS METHOD

The aim of the census was to gather sufficient information from each of the units of the fishery to calculate a rate of catch-per-unit-effort and an accurate estimate of the total catch of black-spotted trout from Yellowstone Lake and River. The data gathered from each fishing party contacted by Fish and Wildlife Service personnel consisted of the number of anglers in the party, the area of fishing, the total hours of actual fishing for all anglers, and the total number of fish taken. With this information, the average effort (number of hours spent by each person in fishing), and the catch-per-unit-effort (number of fish taken in one hour of fishing) could be calculated. Thus, with data concerning the total number of persons fishing, the above rates could be applied and a reasonable estimate of the fishing mortality or total catch could be made.

By a systematic plan of sampling, the above data were collected from each of the separate units of the fishery. In 1950, the data were grouped by two-week periods so that natural changes in fishing success with progress of the season could be evaluated. In 1951, however, the data were collected by 2-week (biweekly) periods following the schedule shown in table 1.

Table 1

Creel census schedule used during 1951 season. The first day of creel census was May 30, the opening day of the fishing season in Yellowstone Park.

	Days in biweekly period													
Fishery Unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Fishing Bridge Dock	X			X			X			X				
Fishing Bridge		X			X			X			X			
Complete River			X			X			X			X		
Complete Shoreline				X			X			X			X	
Incomplete River and Shoreline					X			X			X			X
West Thumb Dock*	X					X			X			X		

*West Thumb dock was censused by Fish and Wildlife Service personnel stationed at Arnica Creek field camp.

Calculations for most units were based on the assumption that the mean of the sampled days in each biweekly period would be representative of all days in that period. Accurate figures on the rowboats and party guideboats and the number of anglers using these facilities were obtained from the boat concessionaire, the Yellowstone Park Company. Thus the calculated means for each biweekly period could be applied to the biweekly totals furnished by the Yellowstone Park Company for deriving the biweekly estimates.

As each unit of the Yellowstone Lake fishery has problems which are unique, and to simplify the presentation of the census results, the individual units have been treated and analysed separately.

FISHING BRIDGE DOCK

Fishing Bridge dock is located on the Yellowstone River immediately downstream from Fishing Bridge (fig. 1). This is the largest and most popular of the docks providing rental boats. The duration of each of the rowboat and guideboat trips is recorded to the nearest tenth of an hour by a recording clock. The Yellowstone Park Company also keeps a record of the number of persons occupying each rented boat. These data have proven to be of great value, for an accurate record of the length of each boat trip and the number of persons making the trip is thus recorded for each day of the season.

Rowboat Fishery:

The Fish and Wildlife Service observer at Fishing Bridge dock recorded the total trip hours for each boat coming into the dock, the number of persons actually engaged in fishing from the boat, and the total number of fish taken by the fishing party. It was assumed that the trip hours approximated the actual fishing hours, for fishable water is encountered immediately after leaving the dock. The area of the lake in which fishing was done was also recorded. The observer was on duty at the dock from 8 a.m. to 5 p.m. Another observer reported to the dock at 6 p.m. and remained until all rental boats had been returned, usually by 8 p.m. In many instances the data from boats which returned between 5 and 6 p.m. were recorded by the dock workers.

During the 1950 season, Fishing Bridge dock was censused every other day, or seven times during each 2-week period. Because of limited personnel and an expanding research program, it was essential to reduce the number of censuses during the 1951 season without materially reducing the accuracy of our estimate. Setting up the hypothesis that there was no difference between the number of parties and persons interviewed on odd and even census days when numbered consecutively from the first census day of the season, an adjusted Chi-square test was made using one-half of the season's total as the expected number. The results of this test are shown in table 2.

Table 2

Chi-square test of 1950 data from Fishing Bridge Dock

	Total	Odd	Even	Expected	Adj. X^2	d.f.
Parties	3741	1879	1862	1870.5	0.0684	1
Persons	9034	4576	4458	4517.0	1.5152	1

As neither of the Chi-square values were significant,[1/] the hypothesis was accepted. It was concluded that half as many days would sample one-half of the censused fishing parties and fishermen. Thus, if the mean catch-per-unit-effort for each of the halves were not significantly different, the estimate made from either half of the census days would produce the same seasonal estimate as that from the other half. Catch-per-unit-efforts were calculated for each of the census days of 1950, and it was found that the means for the odd and even census days were exactly equal, to three decimal places, 0.739. With this information, it was felt that with confidence we could reduce the number of census days during the 1951 season to four days for each two-week period without decreasing the accuracy of the final estimate.

A summary of the data collected from the rowboat rentals at Fishing Bridge dock during the 1950 and 1951 seasons is shown in table 3.

Table 3 shows a noticeable similarity in the effort, catch-per-unit-effort, and the estimate of the total number of fish taken by rowboats from Fishing Bridge dock for the two years. As the catch-per-unit-effort is an index of the relative success of fishing, it would be essential to know if the slight difference in average catch-per-unit-effort between the two years is significant. A graph of the catch-per-unit-effort values for each 2-week period (fig. 2) for 1950 and 1951 shows them to follow rather closely throughout the season. A graph of the rates of effort shows more distant relationships.

A test of the difference between the variance of biweekly means for each year for catch-per-unit-effort and for effort was not significant at the 0.05 level for rowboat or guideboat fishing at Fishing Bridge or West Thumb dock. Thus, the "t" test was used to test the hypothesis that there was no difference between the grand means of the biweekly means for each unit. The results of the test for the rowboat fishery at Fishing Bridge dock are shown in table 4.

1/ $P = 0.05$ is considered as significant in all tests in this paper.

Table 3

Creel Census Results, Fishing Bridge Dock, Rowboats, 1950 and 1951

		CENSUS RESULTS						Y.P. CO. RECORDS		ESTIMATES	
Year	Bi-wkly Period	Fishing Parties	Fisher-men	Fisherman hours	Catch	Aver. hours per fisherman	Aver. catch per man hour	Fishing Parties	Fisher-men	Total Fish-erman Hours	Total Catch
1950	1	29	60	130.1	22	2.17	0.17	80	168	364.6	62
	2	228	503	1,217.2	487	2.44	0.37	719	1,815	4,428.6	1,639
	3	507	1,177	3,131.2	1,787	2.34	0.50	1,443	3,614	8,456.8	4,228
	4	812	1,908	5,292.9	3,760	2.75	0.73	2,120	5,304	14,586.0	10,648
	5	736	1,756	4,445.8	2,764	2.53	0.65	2,068	5,171	13,082.6	8,503
	6	570	1,155	3,100.1	1,075	2.67	0.37	1,435	3,586	9,574.6	3,543
	7	540	1,191	3,184.5	1,175	2.68	0.35	1,355	3,283	8,798.4	3,079
	8	203	433	1,156.4	374	2.77	0.29	1,100	2,750	7,617.5	2,209
	9	8	19	58.1	12	3.03	0.20	10	36	109.8	22
Total		3,633	8,202	21,716.3	11,456	23.38	3.63	10,330	25,727	67,018.9	33,933
Mean						2.60	0.40				
1951	1	111	262	758.4	258	2.90	0.38	453	1,303	3,778.7	1,436
	2	276	596	1,537.6	832	2.58	0.50	1,207	3,664	9,453.1	4,727
	3	463	1,104	3,349.2	1,938	3.03	0.54	1,966	5,911	17,910.3	9,672
	4	335	827	2,352.2	1,245	2.84	0.54	2,096	6,335	17,991.4	9,715
	5	324	792	2,573.2	963	3.25	0.38	1,299	3,913	12,717.3	4,833
	6	356	834	2,602.3	1,022	3.12	0.40	1,321	3,980	12,417.6	4,967
	7	143	379	823.6	207	2.17	0.30	652	1,964	4,261.9	1,279
	8	23	53	116.1	48	2.19	0.29	168	508	1,112.5	323
Total		2,031	4,847	14,112.6	6,513	22.08	3.33	9,162	27,578	79,642.8	36,952
Mean						2.76	0.42				

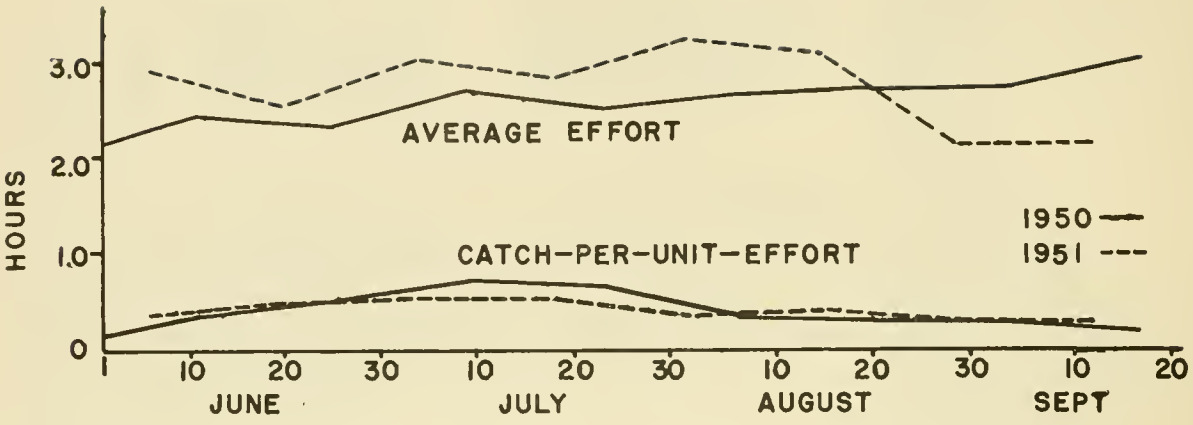

Figure 2. Biweekly of effort and catch-per-unit-effort plotted against the mid-point of each period; rowboat fishery, Fishing Bridge dock, 1950 and 1951.

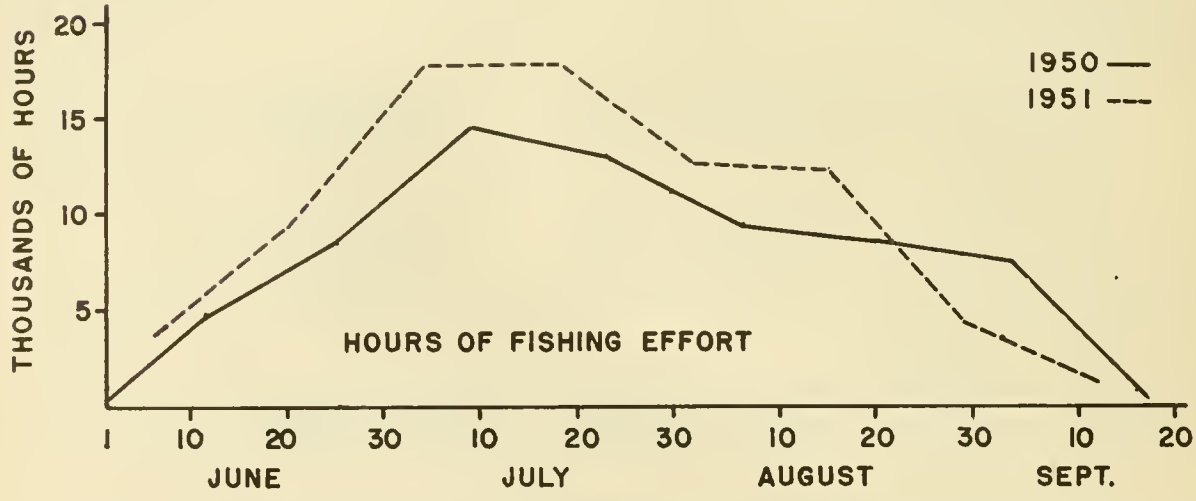

Figure 3. Total hours of fishing effort of biweekly periods plotted against the mid-point of each period; rowboat fishery, Fishing Bridge dock, 1950 and 1951.

Table 4

"t" test of catch-per-unit-effort and effort, rowboat fishery, Fishing Bridge dock, 1950 and 1951

	Catch-per-unit-effort		Effort	
Year	1950	1951	1950	1951
Biweekly means	0.17	0.38	2.17	2.90
	0.37	0.50	2.44	2.58
	0.50	0.54	2.34	3.03
	0.73	0.54	2.75	2.84
	0.65	0.38	2.53	3.25
	0.37	0.40	2.67	3.12
	0.35	0.30	2.68	2.17
	0.29	0.29	2.77	2.19
	0.20		3.03	
Grand mean	0.4033	0.4162	2.598	2.760
n	9	8	9	8
"t"	0.194 at 15 d.f.		0.989 at 15 d.f.	

In both cases the "t" values were not significant. It was thus concluded that there was no significant difference in either the average effort or catch-per-unit-effort between the 1950 and 1951 seasons. Any difference in total catch could then be attributed to an increase or decrease in number of anglers and not to any change in availability of fish to the fisherman. As shown in a graph of total hours of fishing by two-week periods (fig. 3), the total hours of fishing for 1951 is higher than for 1950. Because there is no significant difference in the average effort rates, the total fishing hours is directly related to the number of fishermen. We would thus expect the catch to be relatively larger for 1951. Although not as pronounced as is the amount of effort, the distribution of the catch (fig. 4) is generally higher, verifying the expectation.

Guideboats:

During the 1950 season, five guideboats operated from Fishing Bridge dock. In 1951, however, only one guideboat operated from this dock, but five operated from Lake Dock, less than one mile distant and immediately in front of the Lake Hotel (fig. 1). Although not operating from the same dock, the guideboats fished the same waters throughout the summer of 1951 and were therefore considered as one unit in this analysis. There was no change in areas fished by guideboats from 1950 to 1951 even though there was a change in location of docks. The data gathered from this unit are summarized in table 5.

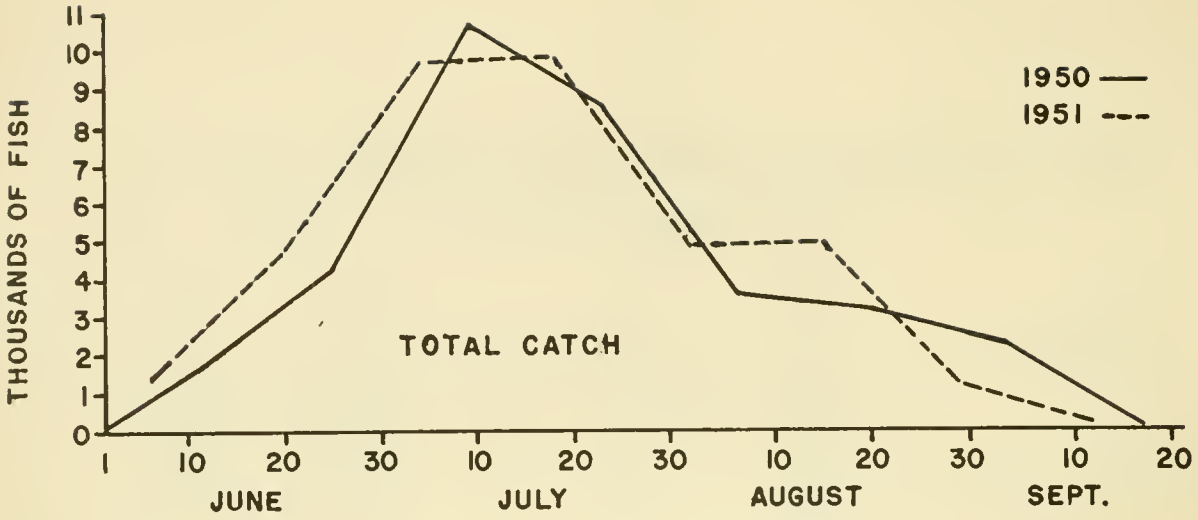

Figure 4. Total catch of biweekly periods plotted against the mid-point of each period; rowboat fishery, Fishing Bridge dock, 1950 and 1951.

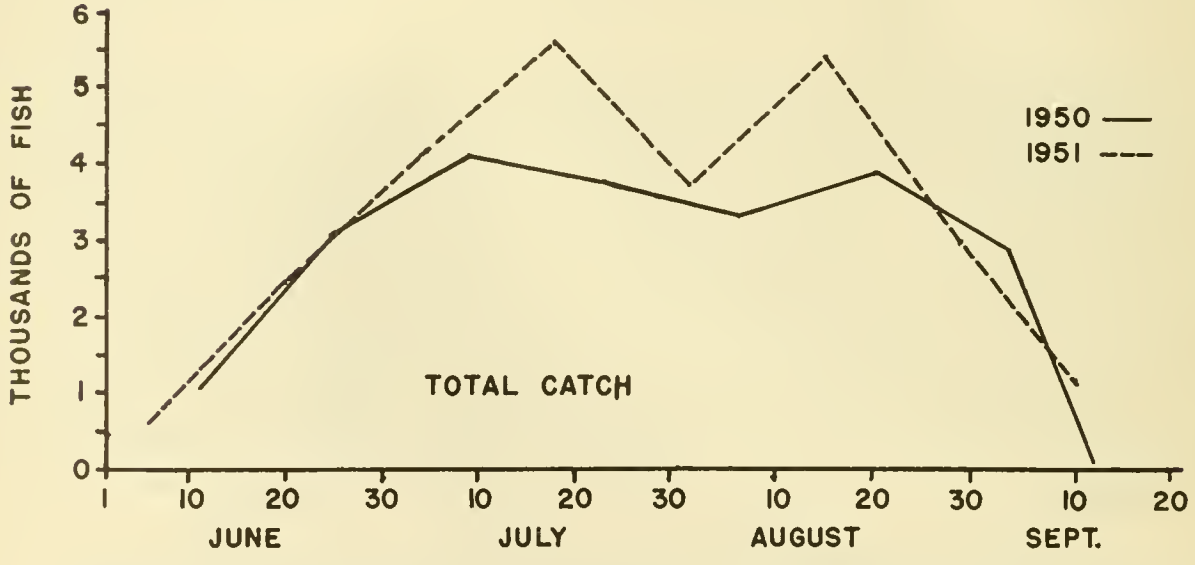

Figure 5. Total catch of guideboats at Fishing Bridge dock, 1950 and 1951. Catch of two-week periods plotted against the mid-point of each period.

Table 5

Creel Census Results, Fishing Bridge Dock, Guideboats, 1950 and 1951

		CENSUS RESULTS						Y.P. CO. RECORDS		ESTIMATES	
Year	Biweekly Period	Fishing Parties	Fisher-men	Fisherman hours	Catch	Aver. hours per fisherman	Aver. catch per man hour	Fishing Parties	Fisher-men	Total Fish-erman hours	Total Catch
1950	1	42	120	246.4	367	2.02	1.48	99	350	707.0	1,046
	2	78	244	526.0	1,029	2.15	1.93	207	743	1,597.4	3,083
	3	120	404	816.4	1,830	1.99	2.32	256	901	1,793.0	4,160
	4	83	284	578.4	1,284	2.04	2.34	225	789	1,609.6	3,767
	5	96	320	723.1	1,420	2.29	1.96	211	739	1,692.3	3,317
	6	108	350	833.1	1,584	2.40	1.96	232	822	1,972.8	3,867
	7	71	202	403.6	919	1.99	2.26	186	652	1,297.5	2,932
	8	4	10	27.0	49	2.74	1.80	6	20	54.8	99
	Totals	602	1,934	4,254.0	8,482	17.62	16.05	1,422	5,016	10,724.4	22,271
	Means					2.20	2.01				
1951	1	40	134	309.1	430	2.31	1.39	62	198	457.4	636
	2	104	341	657.6	1,485	1.93	2.26	164	555	1,071.2	2,421
	3	183	600	1,115.8	2,804	1.86	2.51	241	887	1,649.8	4,141
	4	218	765	1,490.2	3,673	1.95	2.46	325	1,160	2,262.0	5,564
	5	155	535	1,030.3	2,325	1.93	2.26	232	851	1,642.4	3,712
	6	187	634	1,398.3	2,795	2.21	2.00	322	1,227	2,711.7	5,423
	7	164	537	1,218.7	2,155	2.27	1.77	199	746	1,693.4	2,997
	8	51	133	263.3	620	1.98	2.35	75	258	510.8	1,200
	Total	1,102	3,679	7,483.3	16,287	16.44	17.00	1,620	5,882	11,998.7	26,094
	Means					2.055	2.125				

As there was no Fish and Wildlife Service observer stationed at Lake Dock, the values in the table for 1951 are based on accurate records kept by guides in the fishing record books furnished by the Fish and Wildlife Service.

Again, "t" tests of the grand means of the means of biweekly periods for the two seasons were made for both rates of effort and catch-per-unit-effort. As in the rowboat analysis, no significant difference was indicated (table 6).

Table 6

"t" test of catch-per-unit-effort and effort, guideboat fishery, Fishing Bridge Dock, 1950, 1951

	Catch-per-unit-effort		Effort	
Year	1950	1951	1950	1951
Biweekly means	1.48	1.39	2.02	2.31
	1.93	2.26	2.15	1.93
	2.32	2.51	1.99	1.86
	2.34	2.46	2.04	1.95
	1.96	2.26	2.29	1.93
	1.96	2.00	2.40	2.21
	2.26	1.77	1.99	2.27
	1.80	2.35	2.74	1.98
Grand mean	2.006	2.125	2.202	2.055
n	8	8	8	8
"t"	0.697		1.306	
d.f.	14		14	

The increase in both number of parties and number of persons fishing from guideboats is again considered the factor responsible for the increase in total catch from this unit of the fishery (fig. 5). The results do not suggest either an increase or decrease in the availability of fish to the fisherman.

Table 7

Creel Census Results, West Thumb Dock, Rowboats, 1950 and 1951

		CENSUS RESULTS						Y.P.CO. RECORDS		ESTIMATES	
Year	Bi-wkly period	Fishing Parties	Fisher-men	Fisherman hours	Catch	Aver.hours per fisherman	Aver.catch per man hour	Fishing Parties	Fisher-men	Total fish-erman hours	Total Catch
1950	1	104	264	766.0	471	2.74	0.67	247	622	1,704.3	1,141
	2	183	445	1,283.2	673	2.92	0.54	572	1,387	4,050.0	2,187
	3	292	731	2,387.6	1,010	3.21	0.38	931	2,329	7,476.1	2,841
	4	234	583	1,840.0	1,030	3.06	0.52	832	2,110	6,456.6	3,357
	5	211	505	1,578.4	799	3.13	0.52	785	1,998	6,253.7	3,252
	6	214	509	1,596.5	993	3.01	0.58	834	2,085	6,275.8	3,640
	7	78	185	459.5	258	2.38	0.53	491	1,230	2,927.4	1,552
Totals		1,316	3,222	9,911.2	5,234	20.45	3.74	4,692	11,761	35,143.9	17,970
Means						2.92	0.53				
1951	1	24	56	134.4	94	2.40	0.57	180	472	1,132.8	646
	2	134	298	710.4	478	2.38	0.70	639	1,815	4,319.7	3,024
	3	122	286	787.8	283	2.75	0.37	700	2,076	5,709.0	2,112
	4	170	385	1,121.5	762	2.91	0.68	1,026	3,053	8,884.2	6,041
	5	147	371	1,156.5	788	3.12	0.68	754	2,308	7,200.9	4,897
	6	208	546	1,644.4	1,029	3.01	0.59	924	2,728	8,211.3	4,845
	7	147	394	1,099.0	537	2.79	0.50	546	1,605	4,477.9	2,239
Totals		952	2,336	6,654.0	3,971	19.36	4.09	4,769	14,057	39,935.8	23,804
Means						2.77	0.58				

WEST THUMB DOCK

Rowboats:

This dock is located on the west shore of West Thumb, and is considerably more isolated from the tourist centers than is Fishing Bridge dock. About 35 rowboats were available for rent at West Thumb dock during each of the seasons of 1950 and 1951. The census was conducted here in the same manner and pattern as was that for Fishing Bridge dock; that is, every other day during the 1950 season, and four times each 2-week period during the 1951 season.

The resulting data for the two years are summarized in table 7.

A graph of the rates of effort and catch-per-unit-effort for 1950 and 1951 (fig. 6) are similar to those of Fishing Bridge dock in that they also are nearly equal for the two years. The "t" test was applied to the grand means of the biweekly means of 1950 and 1951 for both the rate of effort and catch-per-unit-effort (table 8). Neither rate showed significant differences between years. Again, increase in catch is apparently directly related to the increase in number of fishermen and fishing effort (figs. 7 and 8). As at Fishing Bridge, this unit of the fishery does not indicate any change in the number of fish available to the fishermen utilizing the rental boat facilities at West Thumb dock.

Table 8

"t" test of catch-per-unit-effort and effort, rowboat fishery, West Thumb dock, 1950 and 1951

	Catch-per-unit-effort		Effort	
Year	1950	1951	1950	1951
Biweekly means	0.67	0.57	2.74	2.40
	0.54	0.70	2.92	2.38
	0.38	0.37	3.21	2.75
	0.52	0.68	3.06	2.91
	0.52	0.68	3.13	3.12
	0.58	0.59	3.01	3.01
	0.53	0.50	2.38	2.79
Grand mean	0.5343	0.5843	2.9214	2.7657
n	7	7	7	7
"t"	0.884		1.013	
d.f.	12		12	

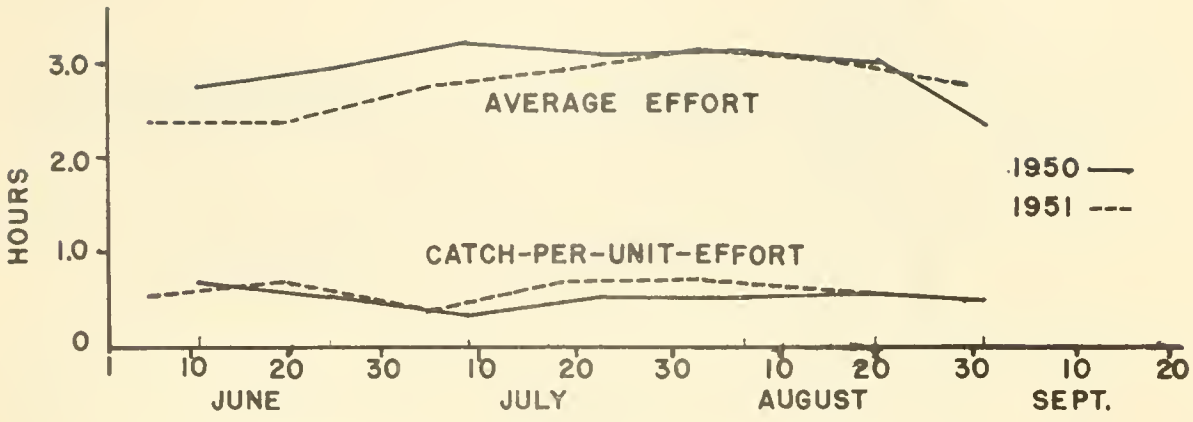

FIGURE 6

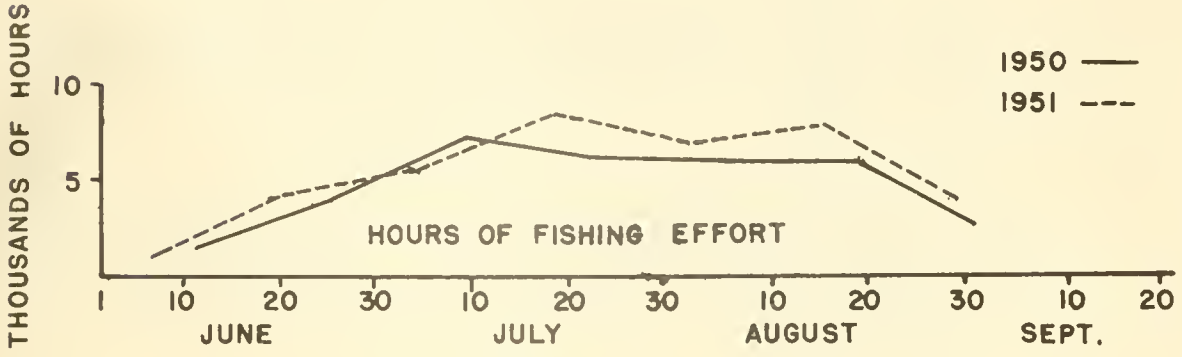

FIGURE 7

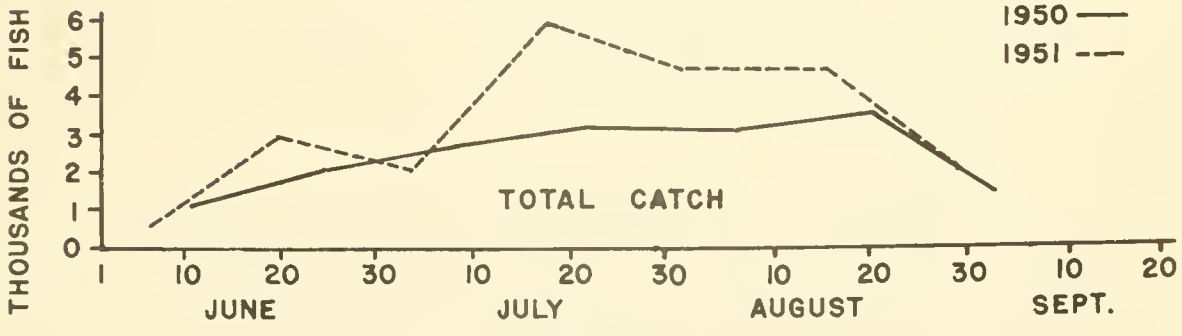

FIGURE 8

Mean rates of effort and catch-per-unit-effort, total hours of fishing effort, and total catch for two-week periods plotted against the mid-point of each two-week period; rowboat fishery, West Thumb dock, 1950 and 1951

Table 9

Creel Census Results, West Thumb Dock, Guideboats, 1950 and 1951

		CENSUS RESULTS						Y.P. CO. RECORDS		ESTIMATES	
Year	Bi-wkly Period	Fishing Parties	Fisher-men	Fisherman hours	Catch	Aver.hours per fisherman	Aver.catch per man hour	Fishing Parties	Fisher-men	Total fish-erman hours	Total Catch
1950	1	19	67	153.0	231	2.19	1.37	38	120	262.8	360
	2	33	102	219.3	410	2.04	2.12	88	273	556.9	1,181
	3	32	131	328.2	619	2.54	1.88	97	302	767.1	1,442
	4	29	97	225.8	476	2.37	2.10	77	238	564.1	1,185
	5	21	66	157.0	272	2.38	1.70	58	185	440.3	748
	6	28	93	222.1	347	2.33	1.57	69	240	559.2	878
	7	9	25	45.3	56	1.69	1.40	43	149	251.8	352
Totals		171	581	1,350.7	2,411	15.54	12.14	470	1,507	3,402.2	6,146
Means						2.22	1.73				
1951	1	2	5	12.5	22	2.50	1.71	19	59	147.5	252
	2	10	31	62.1	85	2.00	1.53	55	194	388.0	594
	3	13	47	103.8	151	2.21	1.34	68	238	526.0	705
	4	11	42	109.6	131	2.61	1.35	56	204	532.4	719
	5	6	21	41.6	83	1.98	1.81	40	154	304.9	552
	6	11	40	103.0	124	2.58	1.28	40	160	412.8	528
	7	10	32	75.0	68	2.34	0.95	33	114	266.8	254
Totals		63	218	507.6	664	16.22	9.97	311	1,123	2,578.4	3,604
Means						2.32	1.42				

Guideboats:

Throughout most of the 1950 season and during the first half of the 1951 season two guideboats operated from the West Thumb dock; during the latter half of the 1951 season, only one boat was available at this location. The guideboats operating from this dock seldom fish in waters outside of the West Thumb (fig. 1). The data furnished by the fishing record books were used as the basis of estimates for the season. Guideboat estimates are summarized for the two seasons in table 9.

The application of the "t" test to the grand means of the biweekly means of both seasons for both the rate of effort and catch-per-unit-effort indicated no significant difference between the two years (table 10).

Table 10

"t" test of catch-per-unit-effort and effort, guideboat fishery, West Thumb dock, 1950 and 1951

	Catch-per-unit-effort		Effort	
Year	1950	1951	1950	1951
Biweekly means	1.37	1.71	2.19	2.50
	2.12	1.53	2.04	2.00
	1.88	1.34	2.54	2.21
	2.10	1.35	2.37	2.61
	1.70	1.81	2.38	1.98
	1.57	1.28	2.33	2.58
	1.40	0.95	1.69	2.34
Grand mean	1.734	1.424	2.220	2.317
n	7	7	7	7
"t"	1.936		0.666	
d.f.	12		12	

From the evidence presented, the guideboat fishery at West Thumb, like that of Fishing Bridge dock, shows no apparent increase or decrease in the availability of fish. This conclusion, along with that of the rowboat fishery at each of the two docks, would indicate a relatively stable condition of the fishery. The noticeable difference evident in the West Thumb guideboat fishery is the reduction in total numbers of fish taken due to the elimination of one of the boats during half of the 1951 season. Had two boats operated from the dock in 1951, the total catch estimate would probably have shown an increase comparable to that of other rental boat fishing activities.

FISHING BRIDGE

Fishing Bridge presented a problem unlike that of any other unit of the Yellowstone Lake fishery. At times there are from 80 to 100 anglers fishing from the Bridge. The continual movement of these anglers to and from the bridge made it possible to contact only a limited number of fishermen. It was found that the most reliable census could be made by having the observer place himself in a position from which he could observe all fish being caught by bridge anglers. The current of the river concentrates the fishing activities on the downstream side of the bridge. A vantage point such as Fishing Bridge dock allowed the observer to see all anglers on the downstream side of the bridge. The count of the number of fish landed on the bridge was made by the hour, while on the half-hour, a count of the number of rods actually engaged in fishing was made. Assuming the count of rods approximated the number of fishing hours, this number, along with the catch, was used in calculating the catch-per-unit-effort. This method of census does not allow for a measure of the number of parties or persons, but neither are essential in calculating the catch-per-unit-effort, the measure of the relative condition of the fishery.

Using the method described above, the 1950 and 1951 estimates are believed to be as accurate as any method which would be feasible. An observer was on duty at Fishing Bridge from 5:00 a.m. until legal fishing ceased at 9:00 p.m.; thus, few if any fish taken on a census day were not accounted for.

For each 2-week period, Fishing Bridge was censused four times, and estimates for each period were calculated. The results of the two years of census of Fishing Bridge are shown in table 11. Rate of catch-per-unit-effort for each year are the mean rates for all 2-week periods in the census.

Table 11

Creel census results, Fishing Bridge, 1950-1951

	Census			Estimate	
Year	Rod Hours	Catch	Catch-per-man-hour	Total Rod Hours	Total Catch
1950	3,408	556	0.16	39,371.6	8,976
1951	10,395	1,647	0.18	41,613.0	8,938

The results of the estimates are surprisingly close. As has been shown previously, the results of other aspects of the Yellowstone Lake fishery have also been very close, and statistical tests have shown them not to be significantly different. There is again no indication of any change in the condition of the fishery as might be demonstrated by the activities of the Fishing Bridge angler success.

It is interesting to note that the success of angling from Fishing Bridge is very closely associated with the movements of fish both to and from the lake by way of the Yellowstone River. This movement has been recognized by tagging studies in the river and the lake. As the bridge is closed to fishing until July 1 of each year, a very early or very late migration of fish under the bridge would most certainly show in the results of the census. This run of fish is usually at its peak in July; thus, if the run were two or three weeks early due to a mild winter with early melting of snows and warming of the water, the success of angling from the bridge would be considerably reduced. The migration of fish is quite clearly reflected in the catch-per-unit-effort plot for 2-week periods in 1951 (fig. 9). This shows the rate to be highest in July, followed by a rapid decrease to the middle of August where it remains relatively constant for the remainder of the season. Moving the plot to a position three weeks earlier, one can visualize the decrease in success of fishing from the bridge.

LAKE SHORE CENSUS

This unit of the fishery consisted of approximately thirty miles of shoreline adjacent to the highway between West Thumb and a point six miles east of Fishing Bridge (fig. 1). During the 1950 season, the observer traveled this distance twice every third day in making the census. One-half of each census day was spent in traveling the thirty miles in one direction and the other half in returning over the same route. During this time he contacted all available anglers along the shoreline. For making comparisons with other stations, these data were also grouped into 2-week periods.

Because of the fact the 1950 census method did not provide for a complete coverage of the lakeshore unit, it was fundamental that a more refined and efficient method of making the shoreline census be developed. With the aid of a statistical analyst, a new method of census was planned for the 1951 season. The 1950 data were revised in the light of the 1951 findings. The new method showed that 20 percent of shore anglers were contacted in 1950, in contrast to 50 percent previously assumed.

The new method was based on what are termed complete and incomplete censuses, each of which was conducted four times during each 2-week period. A complete census required the observer to remain at one location during the entire day and to record the time of arrival and departure of each fisherman in a defined area. The time of the catch of each fish by each fisherman was also recorded. Thus, a pattern of fishing effort by hours, catch by hours, effort per fisherman, and catch per fisherman was obtained. Four such locations were chosen for complete censuses which represented different degrees of fishing pressure along the lake shore, the average of which was assumed to be representative of fishing conditions along the entire shore fishing area. Due to changes in fishing pressure over the season, it was necessary to adjust the complete census areas in order to maintain the average condition desired from the complete censuses.

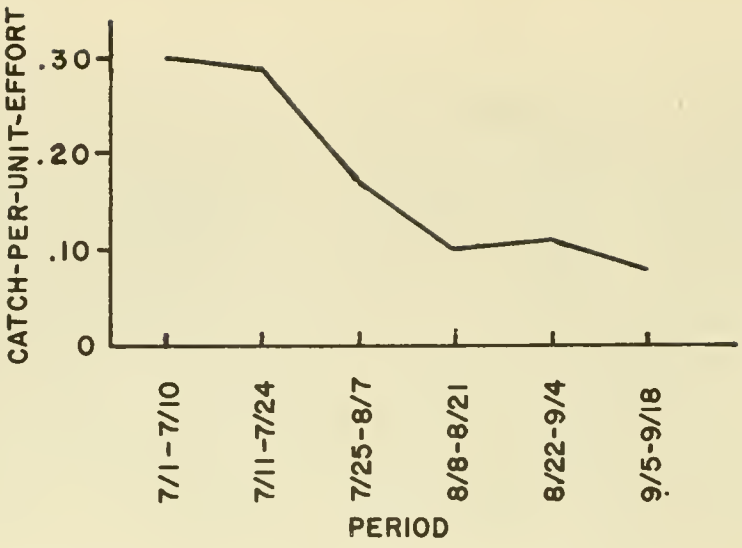

Figure 9. Rate of catch-per-unit-effort at Fishing Bridge plotted against time periods, 1951.

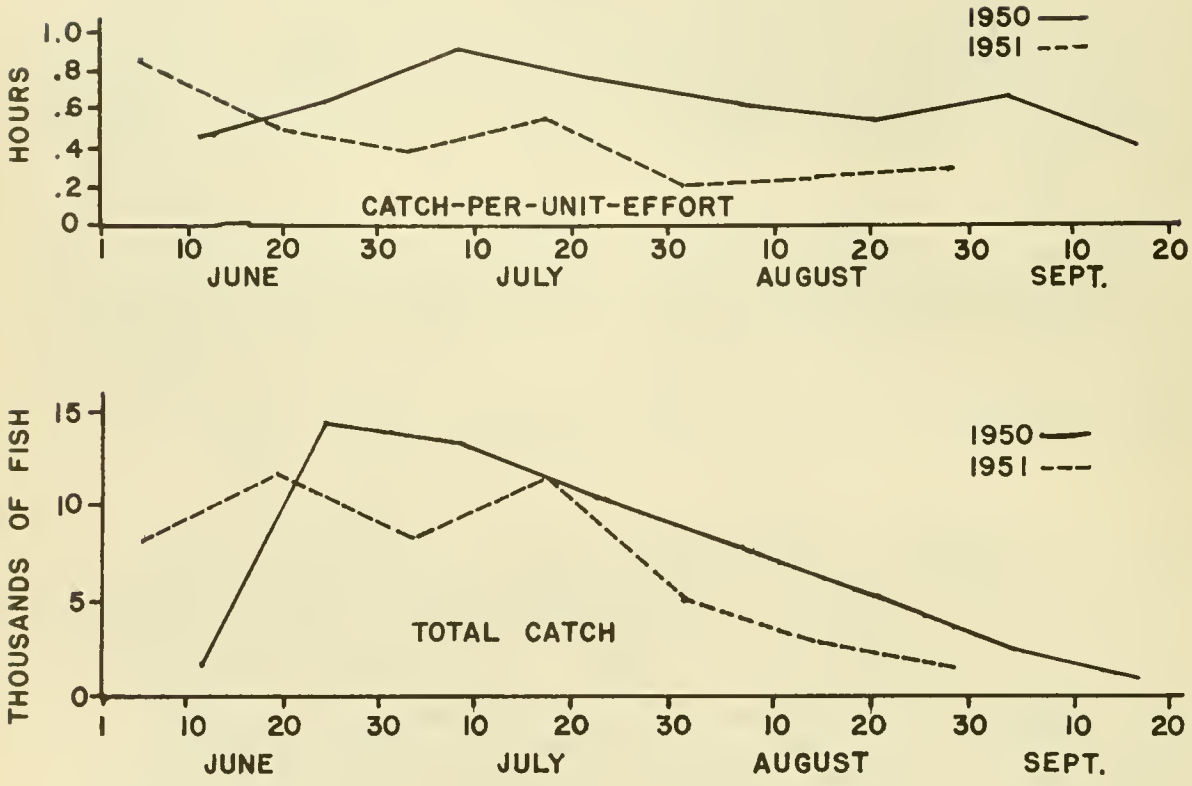

Figure 10. Rate of catch-per-unit-effort and total catch by two-week periods for Yellowstone Lake shoreline fishery, 1950 and 1951.

The four incomplete censuses conducted during each biweekly period were merely counts of the number of fishermen seen every hour while driving the thirty miles of fishable shoreline. Ideally, the driving trip took four hours, with two trips made during the afternoon and two trips made in the morning, of each biweekly period. The morning and afternoon trips started from opposite directions. At some locations along the shoreline, it was necessary for the observer to walk to a vantage point from which he could see the area not readily seen from the highway. Such areas were few in comparison to the entire shoreline, and the time spent at such locations was distributed somewhat randomly by reason of the differences in direction and time of incomplete censuses. The only quantity recorded by the observer when conducting the incomplete census was the number of fishermen seen during each hour of travel.

The data gathered by the complete and incomplete censuses made it possible to estimate the total hours of fishing effort, the total number of fishermen, and the total catch of fish for each 2-week period of shoreline fishing. By substituting the appropriate data in the formula below, the total hours of fishing effort were calculated:

$$N_h = \frac{HD}{d} \qquad \frac{H + R}{H} \qquad \sum_{i=i}^{I} \qquad \frac{K_{ii}}{F_i}$$

where the following notations were used:

N_h = estimate of number of hours (N_c = estimate of catch) (N_f = estimate of fishermen)

H = number of hours of fishing effort recorded in the complete census (data from the four complete census are combined and in calculation considered as one large census). (R number of fishermen, C number of fish taken).

D = number of days in the 2-week period

d = number of days of incomplete census

R = number of fishermen recorded in the complete census

K_{ii} = number of fishermen counted during the i^{th} hour of incomplete census necessarily at the i^{th} length of shoreline

F_i = number of fishermen contributing to H_i fishing hours

$\sum$ = the sum of

Thus, $N_f = \frac{R}{H} N_h$ and $N_c = \frac{C}{H} N_h$

In using the above formula, there was presented a misleading interpretation of the number of fishermen. The calculated number was not truly representative of the number of fishermen, but of the number of "stops" along the shoreline comparable to the duration of the "stops" of fishermen within the complete census areas. The calculated number of fishermen was thus considerably high. By interviewing a sufficient number of anglers to gather data on their average fishing time, it will be possible to adjust this estimate so as to be more representative of the true number of fishermen.

With the formulae above, estimates for the shoreline fishery for the 1951 season were calculated. Results of the revised 1950 and 1951 season are shown in table 12. The rates of effort and catch-per-unit-effort for the two years are mean values of rates calculated for all 2-week periods for each year.

Table 12
Results of shoreline census, 1950 and 1951

Year	No. fishermen	No. hours	No. fish	Effort	Catch-per-fisherman hour
1950	50,260	85,281	55,370	1.79	0.60
1951	114,743	120,651	48,965	1.30	0.43

As there is no method of determining the comparability of the results of the two seasons of shoreline fishing because each was derived by a different method, any conclusions must necessarily be based on the above figures. It is apparent that a considerable increase in effort was expended in 1951 to catch less fish than in 1950. The rates of catch-per-unit-effort verify this and indicate less fish being available to the shoreline fishermen in 1951 (fig. 10).

Table 13 is a summary of the 1951 estimates of hours of effort and of catch by 2-week periods. The standard deviations as shown are not derived from actual variances, but rather from variance estimates of N_h and N_c based on the internal variation within the complete census. These variances fail to include the sampling distribution of the K_{ii}, and are therefore, strictly speaking, not actual variances. The random variables used to compute the "variance estimates" of N_h and N_c are, respectively, the length of time fished by each fisherman and the catch by each fisherman. There is no corresponding random variable for the count of fishermen, and the calculated number is simply a straight ratio estimate of N_f.

Table 13

Estimates of total hours and total catch,
with variances and standard deviations for each 2-week period, 1951

SHORELINE - 1951

Period	N_h	$s^2(N_h)$	$\pm s(N_h)$
5/30-6/12	8,610.08	199,795.06	443.6
6/13-6/26	23,158.04	2,018,049.84	1,420.5
6/27-7/10	22,575.70	962,431.22	980.9
7/11-7/24	22,479.72	3,269,230.06	1,808.1
7/25-8/7	26,409.14	1,073,353.13	1,036.0
8/8-8/21	12,979.26	219,524.36	468.5
8/22-9/4	4,438.69	52,648.48	229.4
	120,650.63		

Period	N_c	$s^2(N_c)$	$\pm s(N_c)$
5/30-6/12	8,323.08	944,732.76	971.9
6/13-6/26	11,806.06	2,698,289.26	1,642.3
6/27-7/10	8,293.11	5,060,703.51	2,249.6
7/11-7/24	11,358.18	5,553,081.34	2,356.5
7/25-8/7	4,965.82	515,095.20	717.7
8/8-8/21	2,961.05	146,924.69	383.3
8/22-9/4	1,258.21	23,446.48	153.1
	48,965.51		

PRIVATE BOAT FISHERY

This unit of the Yellowstone Lake fishery is the most difficult upon which to gather accurate creel census data. It is not feasible to attempt to interview anglers in private boats as they lack any semblance of an orderly fishing pattern. Many of the boats of the larger inboard type do not return to the docks until late at night and sometimes will spend several days in the South or Southeast Arm with the passengers sleeping aboard. As previously noted, the smaller boats on trailers are launched at any number of locations along the shoreline, and, they too, often do not land until late in the evening. Because of the nature of this unit of the fishery, any estimates of total catch would necessarily be based on assumptions for want of more accurate data.

The original 1950 estimate for the trailer-type boats was based on the 1888 boat permits issued by the National Park Service. From observations and contacts with this type of boat fisherman, it was presumed that each boat took at least one limit of fish per day's fishing. As some boats are used on the lake for only one or two days and others for two weeks or longer, it was further presumed that the average number of days of fishing on the lake was three.

Realizing the limitations of the 1950 estimate, a more extensive survey was made in 1951. For collection of more accurate data, a volunteer creel census for trailer-boat anglers was set up in 1951. A card with questions pertinent to the study was attached to each boat permit issued. The cards were to be turned in at the gate as the party left the Park. Of the 2056 boat permits and cards issued, the returns totaled 617, or 30 percent.

At the same time, and as a check of the validity of the volunteer card returns, road blocks were set up one day each week, and all cars with boats were stopped. The road blocks were so placed that only cars leaving the Park were stopped; thus, only these boat fishermen who had completed their fishing activities were interviewed. The same and additional information requested on the volunteer cards was gathered concerning the use of the boat on Yellowstone Lake. Sunday was generally chosen as the day for the road block because many of the boats on trailers are brought into the Park from nearby areas for weekend fishing only.

The season of 1951 was divided into four periods of approximately one month each, and the results of the volunteer census and the road block were compared. For each period the means were calculated for the number of days of fishing on the lake, the number of persons fishing from the boat, the number of hours the boat was used each fishing day, and the catch-per-hour of fishing. The application of the "t" test to the 16 possible comparisons indicated no significant difference in 13 cases (table 14). Two of the three differences were in the number of hours the boat was used each fishing day, and the third difference was in the number of persons fishing from the boat. As the majority of the values of "t" were not significant, it was concluded that the results of the two methods be considered as the same. Because the amount of data from volunteer census cards was considerably greater than that of the road block interviews, the results of the cards (table 15) were used in computing the trailer boat estimates for the 1951 season.

Table 14

Mean number of days fishing on the lake, number of anglers in boats, hours of fishing per boat day, and catch per fisherman hour; road block survey and volunteer census cards, private trailer boats, 1951.

Source	Period	Days on lake	Anglers in boat	Hours per boat day	Catch per man hour
Volunteer cards	1	2.25	3.54*	3.54	1.05
Road block	1	1.38	2.71	3.29	1.33
Volunteer cards	2	2.68	3.22	3.95*	1.04
Road block	2	2.28	3.33	3.31	1.24
Volunteer cards	3	2.88	3.20	3.95*	0.99
Road block	3	2.78	3.22	2.89	1.30
Volunteer cards	4	3.61	3.00	3.36	0.99
Road block	4	3.57	3.24	2.90	1.04

* Significantly different

Table 15

Mean values derived from volunteer creel census cards turned in by trailer-boat fishermen, 1951

Period	Days on lake	Anglers in boat	Per-boat-day hours of fishing	Catch-per-fisherman-hour
5/30-6/26	2.25	3.54	3.54	1.05
6/27-7/23	2.68	3.22	3.95	1.04
7/24-8/20	2.88	3.20	3.95	0.99
8/21-10/1	3.61	3.00	3.36	0.99
Mean	2.86	3.24	3.70	1.02

Catch per boat day - 12 fish

Table 15 indicates that if the 1950 and 1951 seasons are comparable, which is suspected by the closeness of the results of other boat fishing activities, the assumption of an average of three days on the lake for each boat in 1950 was fairly close to the calculated 2.86 days in 1951. The assumption of one limit of five fish per day per boat was greatly divergent from the calculated twelve fish per day of 1951.

The road block data showed that only 78 percent of the boats stopped were used on Yellowstone lake, the others being used on Lewis and Shoshone Lakes, with a few just passing through the Park. It could, therefore, be assumed that 78 percent of the total number of boats to which permits were issued were used on Yellowstone Lake, and this number be used as the basis for calculating the catch estimate. Revising the assumptions made for the original 1950 estimate, it could now be more logically assumed that the two seasons were comparable and estimates calculated accordingly (table 16).

Table 16

Estimates of total catch by
private trailer-type boats for 1950 and 1951

Year	Permits issued	Boats used on lake	Ave. days of fishing	Ave. catch per boat day	Estimate
1950	1,888	1,473	2.85*	12*	50,377
1951	2,056	1,604	2.85	12	54,857

(* Rates assumed to be the same for 1951.)

There are several reasons to believe that the above estimates are very conservative. Road block census results show that roughly 50 percent of the trailer-boats are brought into the Park from the states of Utah and Wyoming. Many of these boats are brought in for use on Yellowstone Lake from one to many times each season. As the one boat permit issued on the first visit is valid for the entire season, there is no count of the number of actual boat trips, but only of the number of permits issued. Interviews with boat owners at road blocks also showed that a considerable number of boats were without permits. Boat owners were often requested to obtain their permits from the Lake Ranger Station, and in many instances this was not done. It is thus impossible to estimate the number of boats without permits used on the lake. The number, however, is believed to be highly significant in making the true estimate of catch. In view of these limitations, the estimates are considered very conservative, and plans for future study will include collection of sufficient data for more accurate estimates of this unit of the Yellowstone Lake fishery.

The 1950 estimate of catch by larger private boats moored at Lake Dock, Fishing Bridge, and West Thumb is based mainly on a record of the fishing done by one of approximately 15 boats of this type on the lake. This boat reported having caught 1,205 fish from June 3 through September 4. As this is known to be one of the more active private boats, it might be assumed that each of the 15 boats took about 300 fish during the 1950 season. This would furnish an estimate of 4,500 fish for the season.

Since it was realized that there was a lack of accuracy of the 1950 estimate, in 1951 boat owners were contacted and two of the largest and most active boats with resident boat operators kept accurate records of their seasonal catches. The Lake Dock manager, realizing the importance of getting the private boat catch, kept an accurate record of the catches of all other private boats moored at this dock. For the three active inboard boats at Fishing Bridge and the two at West Thumb, the same assumption for 1950 of 300 fish per boat has been made for the 1951 estimate. These data provide an estimate for the season as follows:

Source	Catch
Private boat records (two boats)	2,470
Dock manager record (four boats)	1,082
Estimate (three boats at Fishing Bridge Dock)	900
Estimate (two boats at West Thumb dock)	600
	5,052

Combined with the estimate for the private trailer boats for the two seasons, the total catch estimates for the private boat fishery on Yellowstone Lake would amount to 54,877 for 1950 and 59,909 for 1951. Unfortunately, in deriving the estimates as they were, there is no measure of the rates of effort or catch-per-unit-effort upon which to judge the change in relative condition of this unit of the fishery.

YELLOWSTONE RIVER

Because tagging experiments have indicated that trout move freely from the lake into the river, and vice versa, it has been assumed that the fish taken from the river above Yellowstone Falls, a natural barrier, are of the same population as those fish taken from the lake. During the 1951 season, the river fishery was censused in the same manner as the lake shore, that is, by four complete and four incomplete censuses during each two-week period. Using the same formulae as for the lake shore estimates of total hours, fishermen and catch were made for the river fishery for the 1951 season (table 17).

Table 17

Results of Yellowstone River census, 1951

Year	Fishermen	Fisherman Hours	Total catch	Average effort	Catch-per-fisherman-hour
1951	113,891	83,614	19,729	0.73	0.24

As explained in the analysis of the shoreline census for 1951, the number of fishermen is not truly representative of the actual number of fishermen. It is, however, an estimate of the number of fishermen staying in one place and angling as long as was demonstrated by the complete censuses for each two-week period. Assuming the average total fishing time in the 1952 season is no different from that of 1951, this number can be adjusted from the results of future censuses so that it is more representative of the actual number of anglers. The number of fishermen as calculated for 1951 for the river fishery is probably more divergent from the true number than is that for the lake shore. The anglers on the river tend to keep moving along the river bank more than do those along the shoreline; thus the average effort demonstrated by the complete census for the river fishery is considerably smaller than that of the shoreline.

A summary of the 1951 estimates of hours of effort and of catch for the Yellowstone River fishery is shown in table 18. Variance estimates are subject to the same limitations as discussed under the shoreline fishery.

Table 18

Estimates of total hours and total catch,
with variances and standard deviations for each two-week period

YELLOWSTONE RIVER - 1951

Period	N_h	$s^2(N_h)$	$\pm s(N_h)$
7/1-7/10	20,136.83	692,683.17	832.2
7/11-7/24	22,205.81	524,417.04	724.2
7/25-8/7	17,646.46	891,404.67	944.1
8/8-8/21	12,329.24	223,711.65	472.9
8/22-9/4	11,296.16	307,564.28	554.5

Period	N_c	$s^2(N_c)$	$\pm s(N_c)$
7/1-7/10	6,146.19	973,703.60	986.8
7/11-7/24	5,506.56	641,520.64	800.9
7/25-8/7	1,796.73	112,679.54	335.7
8/8-8/21	3,135.76	506,666.44	711.8
8/22-9/4	3,143.28	306,328.38	553.4

CONCLUSION

The results of the two years of creel census on Yellowstone Lake have provided estimates of the total catch for each of the units making up the complex fishing pattern. Limiting factors evident in the 1950 census data allowed for considerable refinement in 1951 operations. There are, however, a few factors as mentioned previously which still limit the accuracy of the total estimate. Recognizing these, it is possible for an even more accurate estimate to be made in future creel census operations on Yellowstone Lake.

Estimates of total catch by units for 1950 and 1951 are shown in table 19. There is in most cases an increase in catch for the different units of the fishery. Exceptions are: guideboat fishing at West Thumb dock, lake shore fishing, and Fishing Bridge. The lower catch for guide-boat fishing at West Thumb in 1951 is directly related to the reduction in number of boats operating from this dock. The lake shore fishing differential may be attributed to the difference in methods of census used in deriving the estimates. Assuming the methods are comparable, the 1951 catch is somewhat lower than that of 1950. The estimates for Fishing Bridge for the two years approximate each other so closely that an assumption of no significant change would seem justified. The grand totals of catch for the Yellowstone Lake fishery for 1950 and 1951, when considering comparable units, amount to 199,993 in 1950, and 207,860 in 1951, an increase of 7,867 fish. Including the Yellowstone River catch of 19,729 fish, the 1951 total is 227,589.

Average catch-per-unit-effort values for each unit of the fishery for the two seasons are also shown in table 19. Although not significantly different, the rates for the rental boat fishing activities tend to be slightly higher in 1951. As the catch-per-unit-effort is considered a reliable index of relative fishing success, it can be concluded that on the average, fishing was better in 1951, although the difference is not great enough to be statistically significant.

The results of the two years of extensive creel census on Yellowstone Lake indicate that increasing fishing pressure is not at the present time causing a reduction in the fish population. Continuous increases in fishing pressure as have been demonstrated in the years following World War II will show their effect on the fishery in time. There is, however, a maximum fishing pressure which can be maintained without serious detrimental effects to the fishery. There is nothing evident from the 1950 and 1951 creel census results to indicate that this point has been reached. Biological studies on size and growth of the Yellowstone Lake trout are being carried on in conjunction with the creel census program. Results of these studies will provide evidence of any change in average size or condition of the fish in the catch or spawning runs. A reduction in average size also may be an indication of over fishing. The entire Yellowstone project is designed in such a manner that indications of failure of the fishery can be readily recognized, and practices can be recommended which will provide a sustained yield population of trout for superior recreational fishing.

Table 19

Summary of number of anglers, catch estimates, and catch-per-unit-effort of all units of Yellowstone Lake fishery, 1950 and 1951

	Number of anglers		Total Catch		Catch-per-unit-effort	
	1950	1951	1950	1951	1950	1951
Private boats (trailer)	-	5,197	50,377	54,857	*	1.02
Private boats (large)	-	-	4,500	5,052	-	-
Guideboats Fishing Bridge	5,016	5,882	22,721	25,688	2.01	2.12
Guideboats West Thumb	1,507	1,123	6,146	3,604	1.73	1.42
Rowboats Fishing Bridge	25,727	27,578	33,933	36,952	0.40	0.42
Rowboats West Thumb	11,761	14,057	17,970	23,804	0.53	0.58
Fishing Bridge	-	-	8,976	8,938	0.16	0.18
Shoreline	50,260	114,743**	55,370	48,965	0.60	0.43
River	-	113,891**	-	19,729	-	0.24
Total (comparable units)	94,271	163,383	199,993	207,860		
Private boats	-	5,197	(included above)	(included above)		
River	-	113,891	-	19,729		
1951 Total		282,471		227,589		

* Assumed the same as 1951

** Not the true number of fishermen (see text)

MATHEMATICAL DERIVATION OF CREEL CENSUS ESTIMATES YELLOWSTONE LAKE SHORELINE

The purpose of this section is to explain the details of the creel census structure as done on Yellowstone Lake. The primary components of the structure are the complete census, which yields characteristics of groups of fishermen in the fishery, and the incomplete census, which furnishes a measure of the total fishing effort. The total catch and total number of fishermen can be estimated from these (data) according to the treatment which follows here.

THE COMPLETE CENSUS

The aim of the complete census is to obtain approximations of the catch-per-unit-of-effort, average effort and catch-per-fisherman, and frequency distribution of fishing effort for the entire Yellowstone fishing group. These approximations can be determined by studying small subgroups, if they are representative of the total fishing group. It is practically impossible to choose samples that perfectly represent the total group, because of the ever-changing pattern of angling distribution on Yellowstone Lake. A practical solution is the selection of four areas, which when pooled are considered to be a representative sample of the fishing population, both with respect to availability of fish and fishing activity. During every biweekly period, each of these four areas is observed for one entire fishing day. Randomization is sought through a sampling schedule that treats each study area on a different day. The pooled observations are henceforth referred to as the complete census. A sample complete census worksheet is given in figure11, together with the numerical quantities which enter into the calculations and derivation.

THE INCOMPLETE CENSUS

In order to estimate the total number of hours of fishing effort along the entire lakeshore during a given biweekly period, some measure of this must be found. A convenient measure is the count of fishermen made by an observer driving along the lakeshore, tabulated according to the time of day that the count is made. Since the frequency distribution is collected (from the complete census) in the pattern of an hourly histogram, it is appropriate to divide the lakeshore into hypothetical strips L_1, L_2, L_3, L_4, each strip being that area covered during one hour of the four hour driving trip. Thus each trip yields a count for each strip.

It is necessary to introduce a probabilistic adjustment to each count, since the observer is unable to view an entire strip from a single vantage point and make an exact count. The resulting number is then adjusted, through the frequency histogram, to give an estimate of the total number of hours of effort that would take place within that strip in the entire fishing day.

Four driving trips along the entire lakeshore are made during each biweekly period, and their results are pooled in such a manner as to give an average estimate of the total number of hours of effort for the lakeshore during this period.

The total number of hours of effort is regarded as being the fundamental quantity under consideration. Multiplying it by suitable ratios, estimates are made for the total number of individual fishermen and the total catch for the biweekly period.

NOTE ON YELLOWSTONE RIVER

The sampling procedure for Yellowstone Lake lends itself well to studying the fishing situation on Yellowstone River. There is, however, one important change. The behavior pattern or river fishermen is to fish in a number of locations, spending a certain amount of time at each. The calculation for N_f, the estimated number of individual fishermen on the river during the biweekly period, must be adjusted to compensate for this tendency. Unaltered, it estimates the total number of fishing stops within the period. It must therefore be divided by the average number of stops made by each fisherman, in order to represent the number of individual fishermen patronizing the fishery. An interview scheme can yield the average number of stops per angler.

If we call this average number of stops per fisherman $\bar{X}$, then in terms of the symbology of the subsequent mathematical treatment,

$$N_f(\text{adjusted for river}) = \frac{H}{R\bar{X}} N_f$$

where N_f is given by a straightforward formula.

Derivation of the Estimates and Variances

It is necessary to define the following quantities:

General

N_h = Estimate of the number of hours of fishing effort on lakeshore during period of D days.

N_f = Estimate of the number of individual fishermen on lakeshore during period of D days.

N_c = Estimates of the total catch on lakeshore during period of D days.

$s^2(N_h)$ = Estimate of variance of N_h due to internal variation in the complete census only.

$s^2(N_c)$ = Estimate of variance of N_c due to internal variation in the complete census only.

D = Number of days in the period under consideration. (In the case of the Yellowstone Lake and River censuses, D = 14.)

T = Length of time unit in which the data are classified. T = 1 hour in this study.

Complete Census

H_i = Number of hours of effort counted during the i^{th} hour.

H_r = Number of hours fished by the r^{th} man during the entire fishing day.

$H = \sum_i H_i = \sum_r H_r$ = Total number of hours of effort recorded during during the complete census.

C_r = Total (day's) catch for the r^{th} man.

i = Index of hour. i = 1, 2, ..., I.

I = Total number of hours during a fishing day.

r = Index of fisherman. r = 1, 2, ..., R.

R = Total number of individual fishermen in the complete census.

C = $\sum_r C_r$ = Total catch during the complete census.

F_i = Number of individual fishermen contributing H_i hours of effort.

F = $\sum_i F_i$.

$\bar{C}$ = C/R = Average catch for each fisherman in the complete census.

$\bar{H}_r$ = H/R = Average time fished by each fisherman in the complete census.

Incomplete Census

Double subscript convention: "ij"

i (first subscript) defines the location (i.e. that strip L_i) covered during the i^{th} hour.

j (second subscript) referes to the j^{th} hour of the day in strip L_i. The actual strip during this particular hour is denoted by L_{ij}. The observer makes his observations on L_{ii}, therefore.

d = Number of "incomplete" trips made during the period of D days.

h_{ij} = Number of hours of effort carried out during the j^{th} hourly interval in L_i, that is, L_{ij}.

f_{ij} = Number of individual fishermen contributing h_{ij} hours of fishing effort to L_{ij}.

k_{ii} = Actual count of fishermen, made while covering L_{ii}.

t_k = Total time fished by the k^{th} fisherman, in some given region along the lakeshore.

$E(t_k)$ = $E(t)$ = Expected time fished by any one fisherman. [$E(t)$ can be thought of as an average, taken over all possible fishermen. It will eventually be replaced by the approximation, $\bar{H}$.]

p_k = p = Probability of observing the k^{th} fisherman in L_{ii}.

H_i^* = $\sum_j h_{ij}$. (Corresponds to H in the complete census.)

F_i^* = $\sum_j f_{ij}$. (Corresponds to F in the complete census.)

It should be noted that there are usually two elements h_{ii}, two elements f_{ii}, and two elements k_{ii}, since the i^{th} hour will (generally) be included twice in the incomplete sampling scheme during each biweekly

period. The symbols h_{ii}, f_{ii}, and k_{ii} must therefore be interpreted (for computational simplicity) as $h'_{ii}+h''_{ii}$, $f'_{ii}+f''_{ii}$, $k'_{ii}+k''_{ii}$, respectively.

In order to clarify the meanings of the quantities pertaining to the complete census, a sample complete census worksheet, together with various marginal summaries, is given in Figure 11.

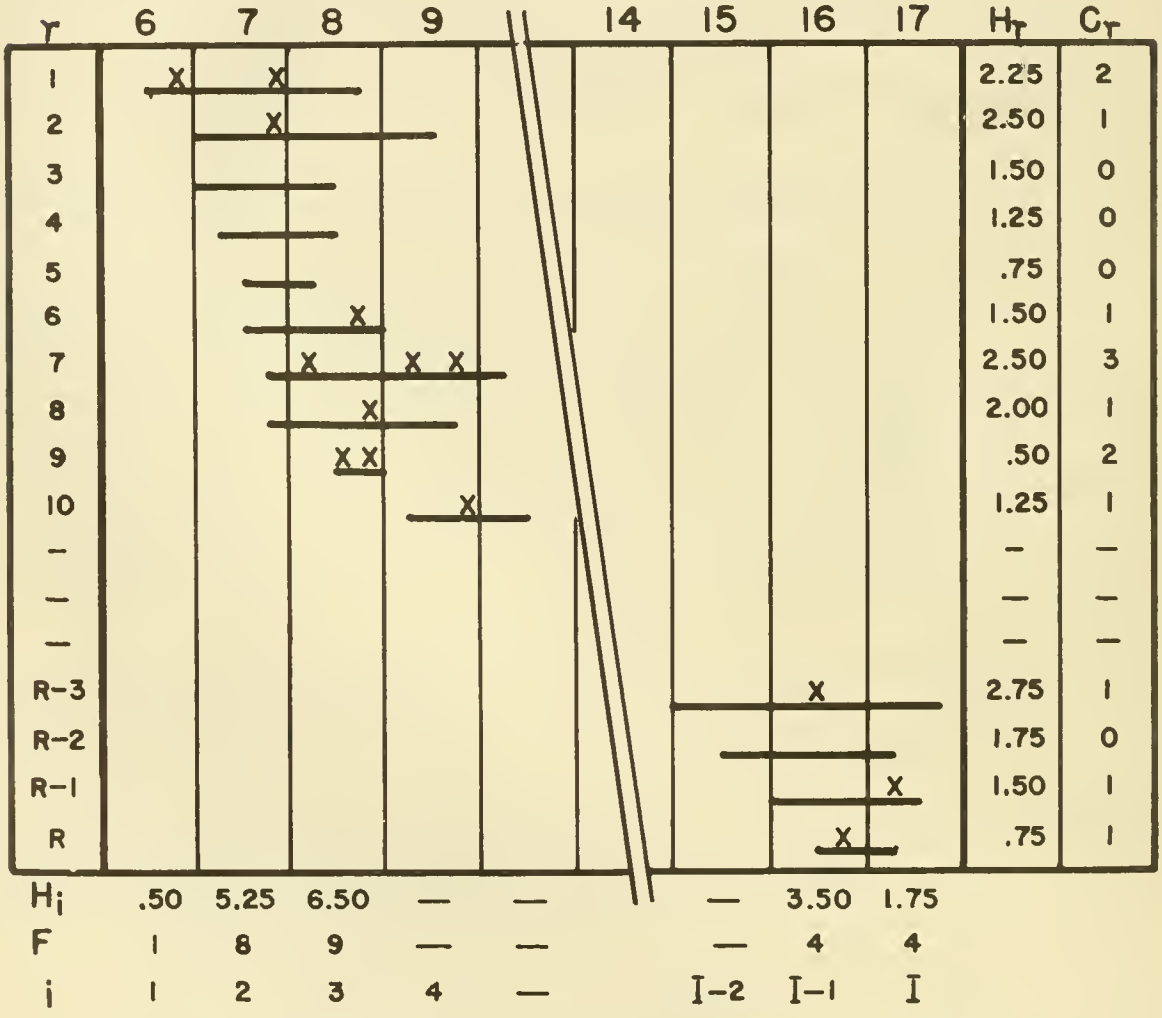

Figure 11. Complete census worksheet with marginal summaries.

Let us consider the frequency histograms for the count of fishermen per hour in the complete census and in L_i, and make the reasonable assumption that they are the same; that is,

$$\frac{F_i}{F} = \frac{f_{ii}}{F_i^*}, \text{ or } \quad F_i^* = \frac{f_{ii}}{F_i} F \tag{1°}$$

Furthermore, let us assume that

$$\frac{F_i^*}{H_i^*} = \frac{F}{H}, \text{ or } \quad H_i^* = \frac{H}{F} F_i^* \tag{2°}$$

Then $$N_h = \frac{D}{d} \sum H_i^* = \frac{D}{d} \sum \frac{H}{F} F_i^* = \frac{DH}{dF} \sum \frac{f_{ii}}{F_i} F = \frac{DH}{d} \sum \frac{f_{ii}}{F_i} \tag{1}$$

We can now express N_c and N_f approximately by

$$N_c = \frac{C}{H} N_h = \frac{DC}{d} \sum \frac{f_{ii}}{F_i} \tag{2}$$

and $$N_f = \frac{R}{H} N_h = \frac{DR}{d} \sum \frac{f_{ii}}{F_i} \tag{3}$$

In order to calculate unbiased variance estimates for the total number of hours of effort, N_h, and the total catch, N_c, it is necessary to know a great deal more about the sampling distribution of the count of fishermen than is now known. Exact variance estimates could be constructed, but they would be of doubtful value, due to the artificial nature of the assumptions that would have to be made. Instead, variance estimates are derived which consider only the variation within the complete census information. These variances may be regarded as being minimum.

Let us now define $x_i = \frac{DH}{d} \frac{f_{ii}}{F_i}$, so that $N_h = \sum_i x_i$. We can rewrite x_i as $x_i = \frac{D}{d} \bar{H}_r \frac{R}{F_i} f_{ii}$, where $\bar{H}_r = H/R$.

If the various x_i can be regarded as being independent (in the probability sense), as we assume they are, then the variance of N_h can be expressed as

$$\text{var}(N_h) = \text{var}(\Sigma x_i) = \Sigma \text{var}(x_i). \tag{4}$$

But $$\text{var}(x_i) = \frac{D^2R^2}{d^2} \left(\frac{f_{ii}}{F_i}\right)^2 \text{var}(\bar{H}_r)$$

or $$s^2(x_i) = \frac{D^2R^2}{d^2} \left(\frac{f_{ii}}{F_i}\right)^2 s^2(\bar{H}_r) \tag{5}$$

Now, since $s^2(\bar{H}_r) = \frac{1}{R} s^2(H_r)$, (5) becomes

$$s^2(x_i) = \frac{D^2R}{d^2} \left(\frac{f_{ii}}{F_i}\right)^2 s^2(H_r)$$

and (4) gives us

$$s^2(N_h) = \frac{R}{R-1} \frac{D^2}{d^2} \Sigma\left(\frac{f_{ii}}{F_i}\right)^2 \left[\Sigma H_r^2 - \frac{(\Sigma H_r)^2}{R}\right] \tag{6}$$

when we insert the well-known formula for the sample variance, $s^2(H_r)$. In a similar manner, we find

$$s^2(N_c) = \frac{R}{R-1} \frac{D^2}{d^2} \Sigma\left(\frac{f_{ii}}{F_i}\right)^2 \left[\Sigma C_r^2 - \frac{(\Sigma C_r)^2}{R}\right]$$

It will be seen from the complete census worksheet that we have no variable corresponding to the actual count of fishermen: the case is simply that of tallying those that are seen. Consequently, we have nothing to correspond to the variables H_r and C_r, and it is therefore impossible to construct a variance estimate for N_f.

Now although we have expressed all our estimates in terms of f_{ii}, this is a number which we do not know. We must estimate f_{ii} from k_{ii}, which is our actual count.

Consider Figure 12, which represents the fishing situation in L_i during the census hour, that is, L_{ii}.

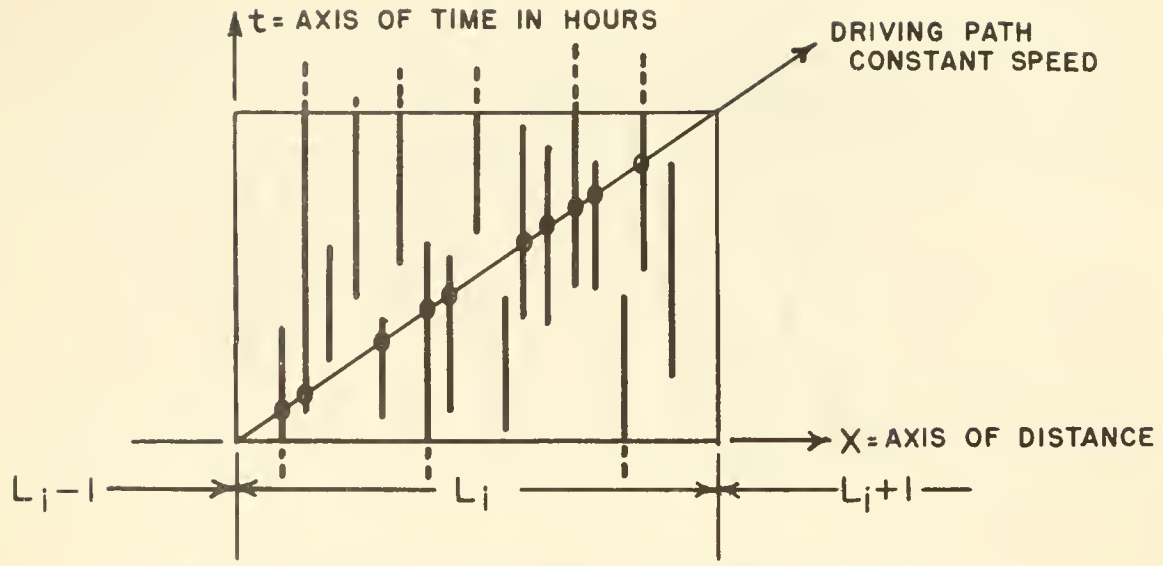

Figure 12. Fishing situation in L_i during the census hour.

Each verticle line represents a fisherman. The position of the line along the X-axis (of distance) establishes the fisherman's location, and its position and length relative to the t-axis (of time) establish the time interval that the man fishes. The number of individual lines which extend within the rectangle constitute f_{ii}. The number of intersections of the diagonal driving path (idealized to be a path of constant speed) with the verticle lines is our count k_{ii}. Clearly, these intersections must lie within the indicated rectangle.

In the case of the Yellowstone Lake census, T = 1 (hour). In certain cases, however, it might be necessary or advisable to consider a frequency histogram (complete census) divided into cells of width T (hours) each; hence the general treatment is presented. here.

The probability "p" of observing the "average" fisherman is given by

$$p = \frac{k_{ii}}{f_{ii}} \tag{8}$$

and it is this expression which we wish to evaluate.

Suppose the k^{th} fisherman contributes t_k hours of effort ($k = 1, 2, \ldots, f_{ii}$). Let us replace Figure12 by an idealized situation where each of the f_{ii} fishermen fish the same expected time $E(t_k) = E(t)$. This gives us Figure13.

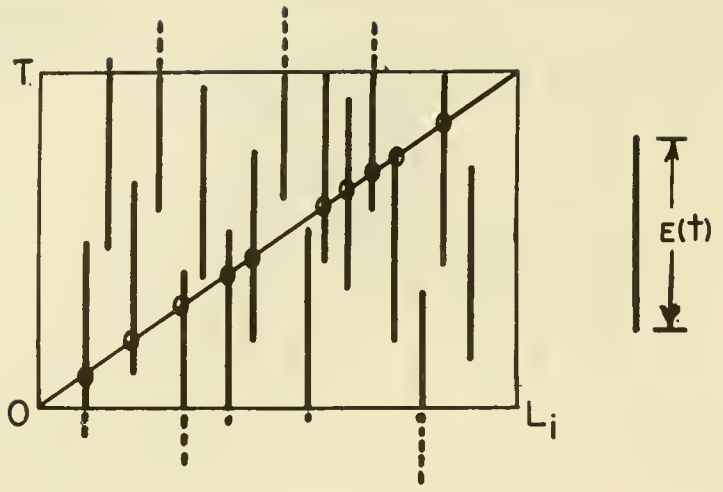

Figure 13. Fishing situation in which each fisherman fishes the same expected time.

A consistent estimate of p is still k_{ii}/f_{ii}, and p can be regarded as the probability that any (unspecified) verticle line will be intersected by the driving path.

Figure14 is equivalent to Figure13. In Figure14, each verticle line is replaced by a point at its center, the driving path diagnol is replaced by a strip of width E(t), and the rectangular area is enlarged by an amount one-half E(t) at top and bottom. Now, p is the probability that a given point will fall within this strip.

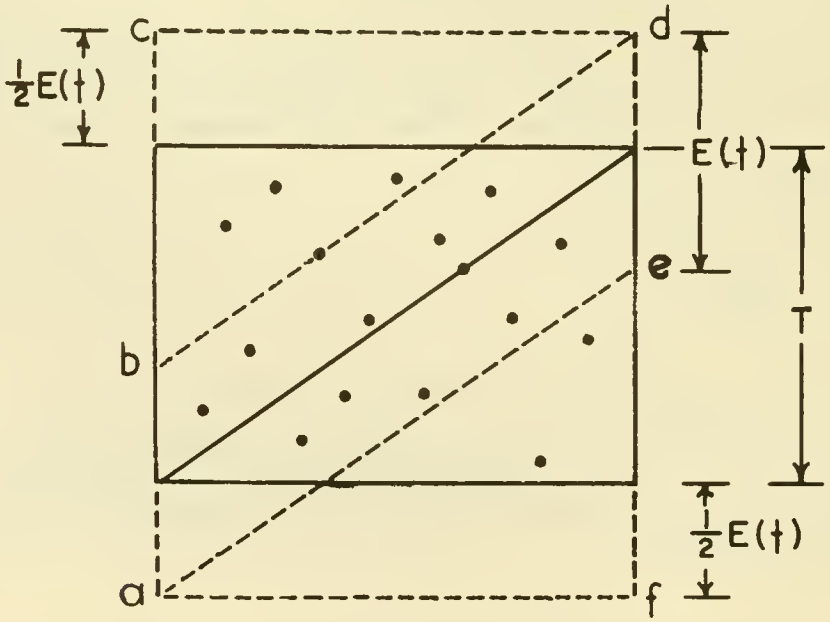

Figure14. Modification of Figure13, with lines replaced by dots and the driving path replaced by a strip.

The concentration of fishing effort depends on time, but if we assume that for a given hour (that is to say, in any L_{ii}) the fishing intensity is independent of time [We are effectively doing this when we choose our cell width to be one hour in the complete census.], and L_i is sufficiently large so that (on the average) a fisherman is equally likely to fish at any location, then (8) becomes

$$p = \frac{\text{area abde}}{\text{area acdf}} = \frac{E(t)}{T+E(t)} \tag{9}$$

and it should be mentioned that for greatest reliability, E(t) must be small compared to T. (This should be considered when selecting the value of T for the experiment.) These various assumptions are equivalent to saying that the distribution of dots within acdf is random; i.e. independent of time and location.

Introducing the approximation $E(t) = \bar{H}_r = H/R$, equation (9) becomes

$$p = \frac{H/R}{T+H/R} = \frac{H}{TR+H} \tag{10}$$

Since (8) and (10) are equivalent, subject to our approximation, we can equate them to obtain the estimate for f_{ii}, which is

$$f_{ii} = \frac{k_{ii}}{p} = \frac{TR+H}{H}$$

In terms of this expression, we can now rewrite equations (1), (2), (3), (6), and (7) as

$$N_h = \frac{DH}{d} \left(\frac{TR+H}{H}\right) \Sigma \frac{k_{ii}}{F_i} \tag{11}$$

$$N_f = \frac{DR}{d} \left(\frac{TR+H}{H}\right) \Sigma \frac{k_{ii}}{F_i} = \frac{R}{H} N_h \tag{12}$$

$$N_c = \frac{DC}{d} \left(\frac{TR+H}{H}\right) \Sigma \frac{k_{ii}}{F_i} = \frac{C}{H} N_h \tag{13}$$

$$s^2(N_h) = \frac{R}{R-1} \frac{D^2}{d^2} \left(\frac{TR+H}{H}\right)^2 \Sigma\left(\frac{k_{ii}}{F_i}\right)^2 \left[\Sigma H_r^2 - \frac{(\Sigma H_r)^2}{R}\right] \tag{14}$$

$$s^2(N_c) = \frac{R}{R-1} \frac{D^2}{d^2} \left(\frac{TR+H}{H}\right)^2 \Sigma\left(\frac{k_{ii}}{F_i}\right)^2 \left[\Sigma C_r^2 - \frac{(\Sigma C_r)^2}{R}\right] \tag{15}$$

These equations, (11), ..., (15), are our desired estimators.

Interior--Duplicating Section
Washington, D. C.